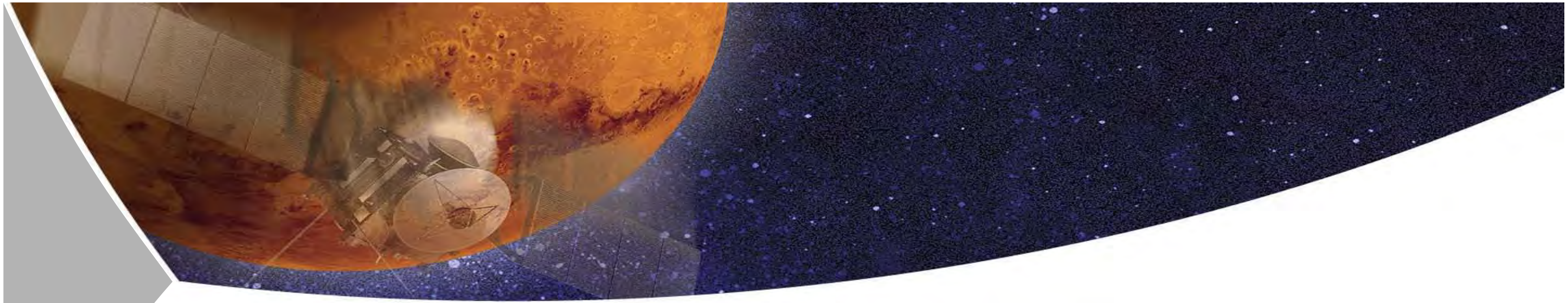


Space Robotics Planetary Exploration - a DLR Perspective

Bernd Schäfer

Deutsches Zentrum für Luft- und Raumfahrt (DLR)
(German Aerospace Center)

Robotics and Mechatronics Center (RMC)

AirTec - SpaceWorld, Frankfurt, 5-7 Nov 2013

Deutsches Zentrum für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

Planetary Exploration

Search for traces of past and present life
Characterize planetary environment
Prepare for human exploration

Exploration technologies for Moon, Mars or other celestial bodies in our solar system.
DLR Robotics and Mechatronics Center:
We are contributing since many years to this ambitious endeavour.

Major Topics of R&D:

(1) Development of mission scenarios for **robotic exploration**

(2) Mobility analyses and realizations for exploration in **complex planetary surface topologies**

(3) Modelling, simulation and optimization of **mobile system dynamics** behaviour on uneven surfaces

(4) Verification and validation of simulated dynamics and performance proving of optimized mobile systems in realistic **ground-based testbeds**

(5) Autonomy increase while using in-house developed localization and navigation methods and algorithms based on **visual odometry** and others.

Development and Utilization of Robotics Exploration Technologies

with Example on

Planetary Wheeled Rovers

Localization and Navigation, Autonomy and Perception:

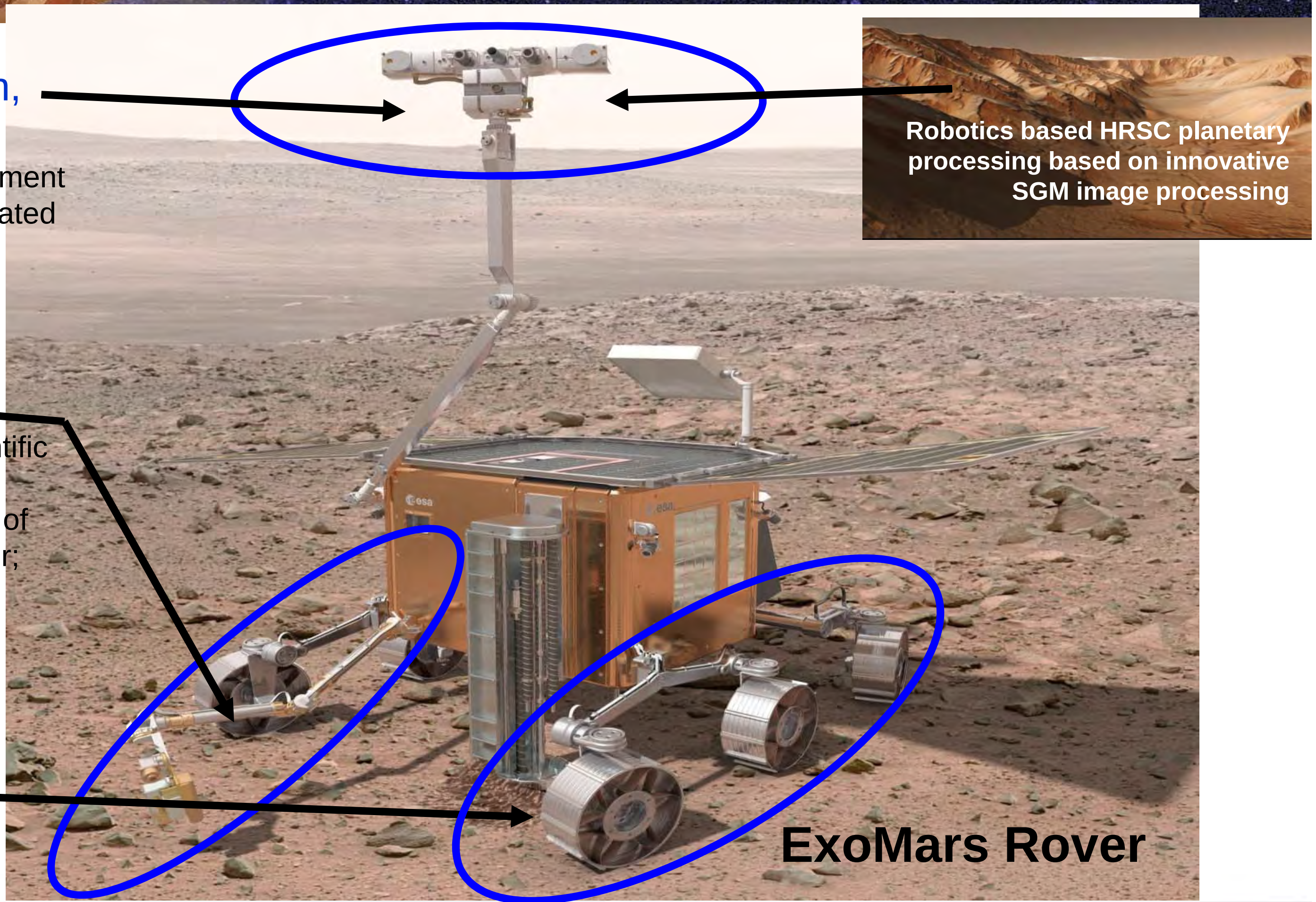
DTM / DEM: 3D-Mapping of environment based on stereo cameras, accomodated on rover and on orbiter
Visual odometry → SGM algorithm (Semi-Global Matching)

Manipulability

Positioning and deployment of scientific instruments on planetary surface;
Acquisition, transport and handover of soil samples, for processing on rover;
Set-up and assembly of modules
→ Build a base station;
Inspection

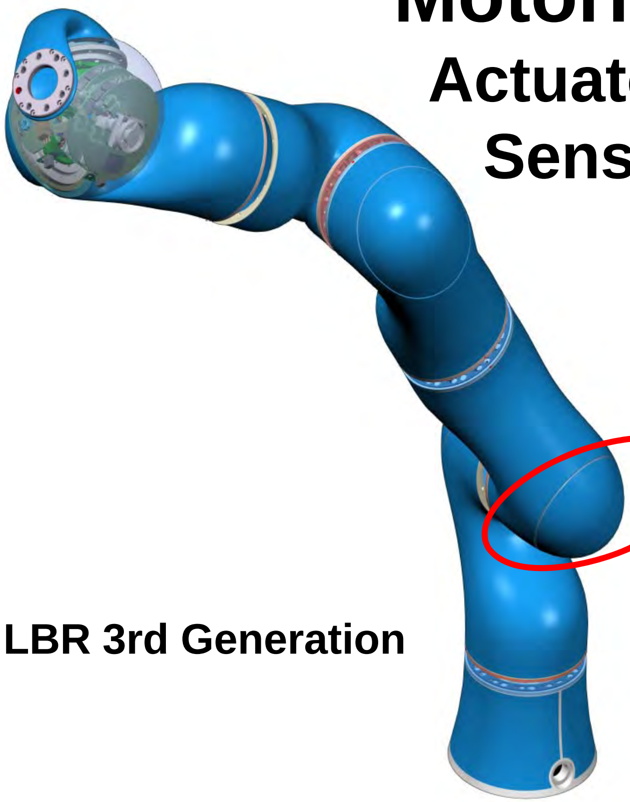
Mobility

Not only wheels:
also legs, legs + wheels, hybrids, …

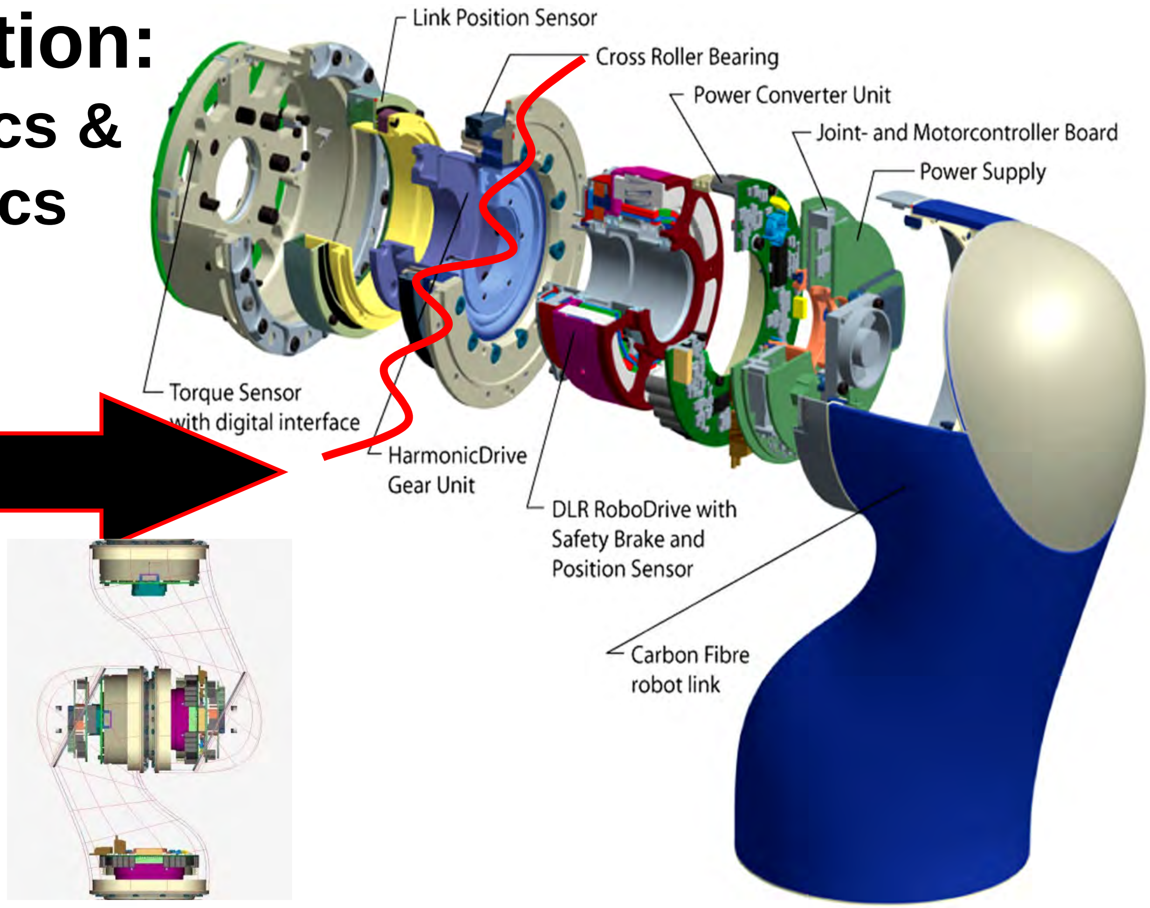


At DLR's RMC
Developed Technologies
to be Utilized for Exploration

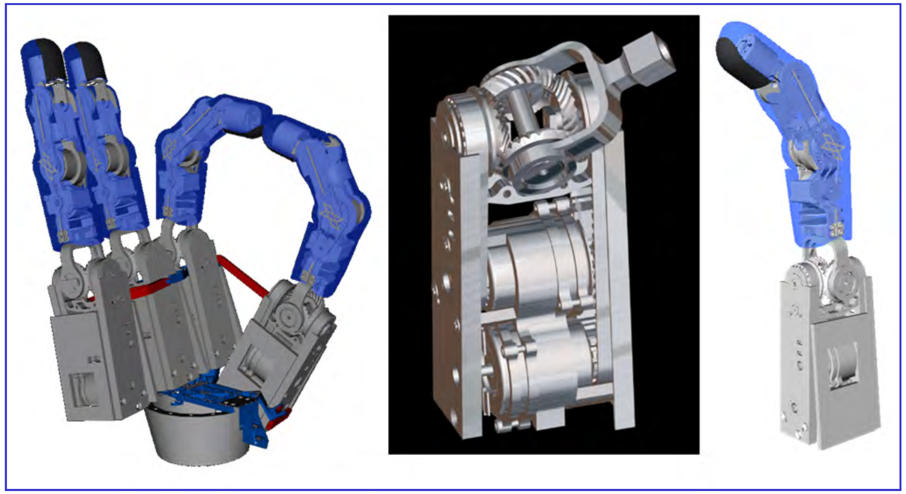
Motorization:
Actuatorics & Sensorics



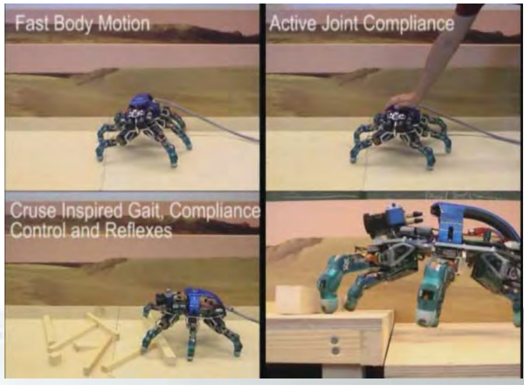
LBR 3rd Generation



Some Selected (Terrestrial) R&D Applications



DLR 4-Finger Hand

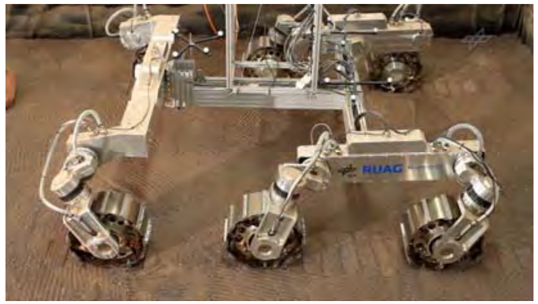


DLR crawler, 6-legged

Rollin‘ Justin with 51 DOF

Rovonaut - Simulation

ExoMars BB1



Rollin-Justin-KinematicChain-Circle

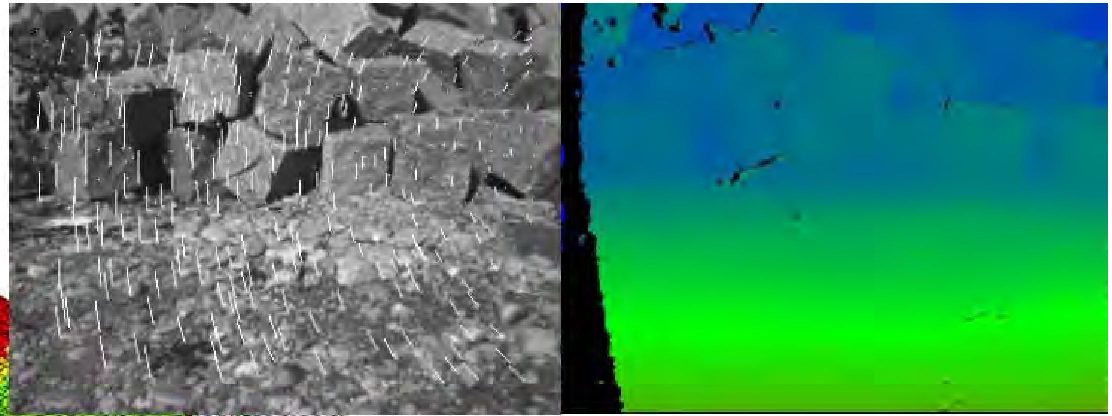
Rollin-Justin

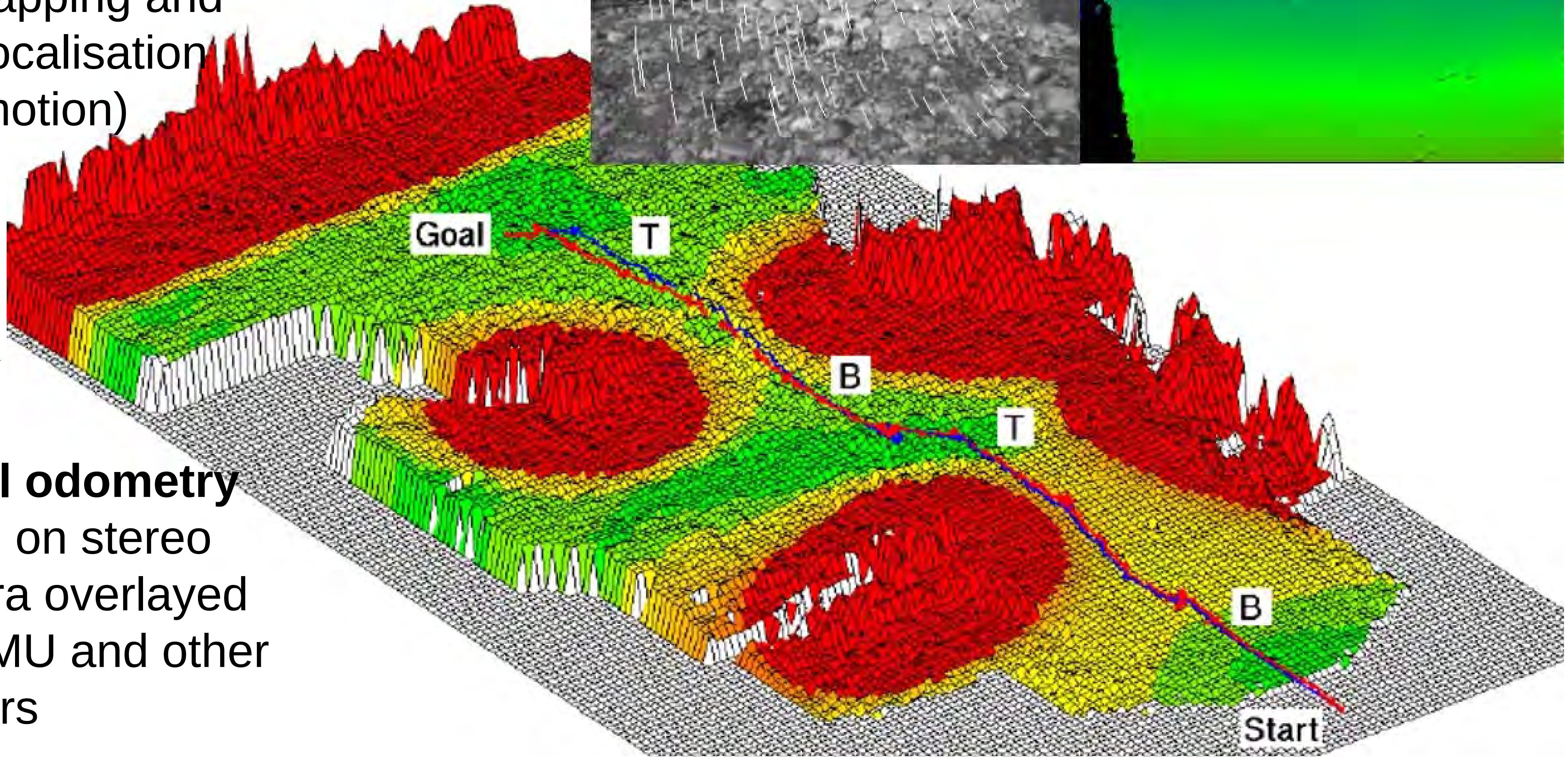
RoverMitTorso_V3_MPEG4 - Verknüpfung

**Rovonaut =
Rover + Astronaut**

Autonomous Navigation:

3D Mapping and
Self-localisation
(egomotion)



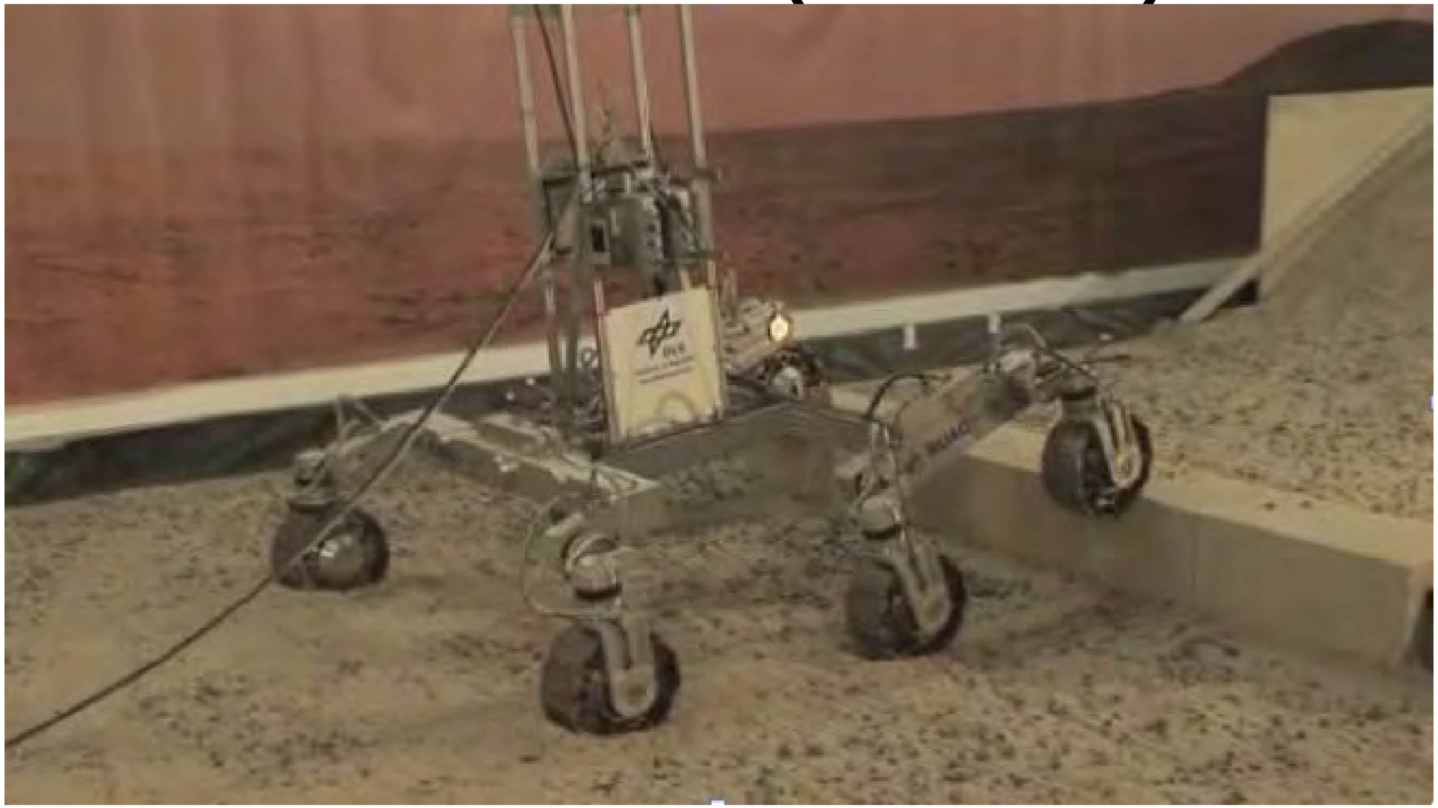


Visual odometry
based on stereo
camera overlayed
with IMU and other
sensors

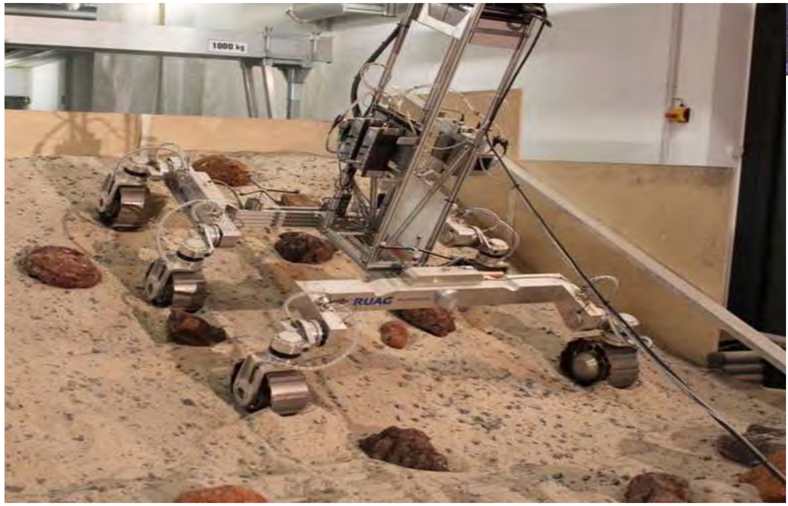

DLR - Crawler
Walking robot equipped with
stereo cameras and IMU

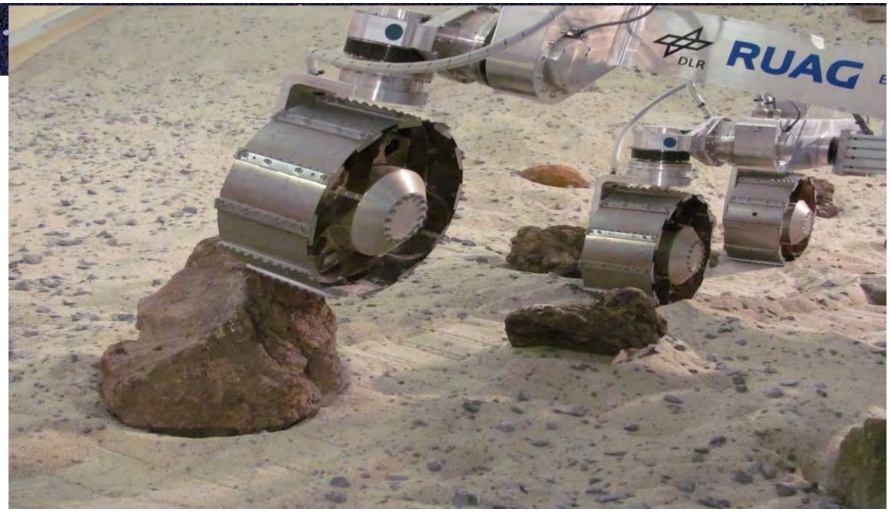
Our Begin → Mars Rover ExoMars (ESA 2018)

Trafficability:
Modelling,
Simulation &
Verification by
Testing



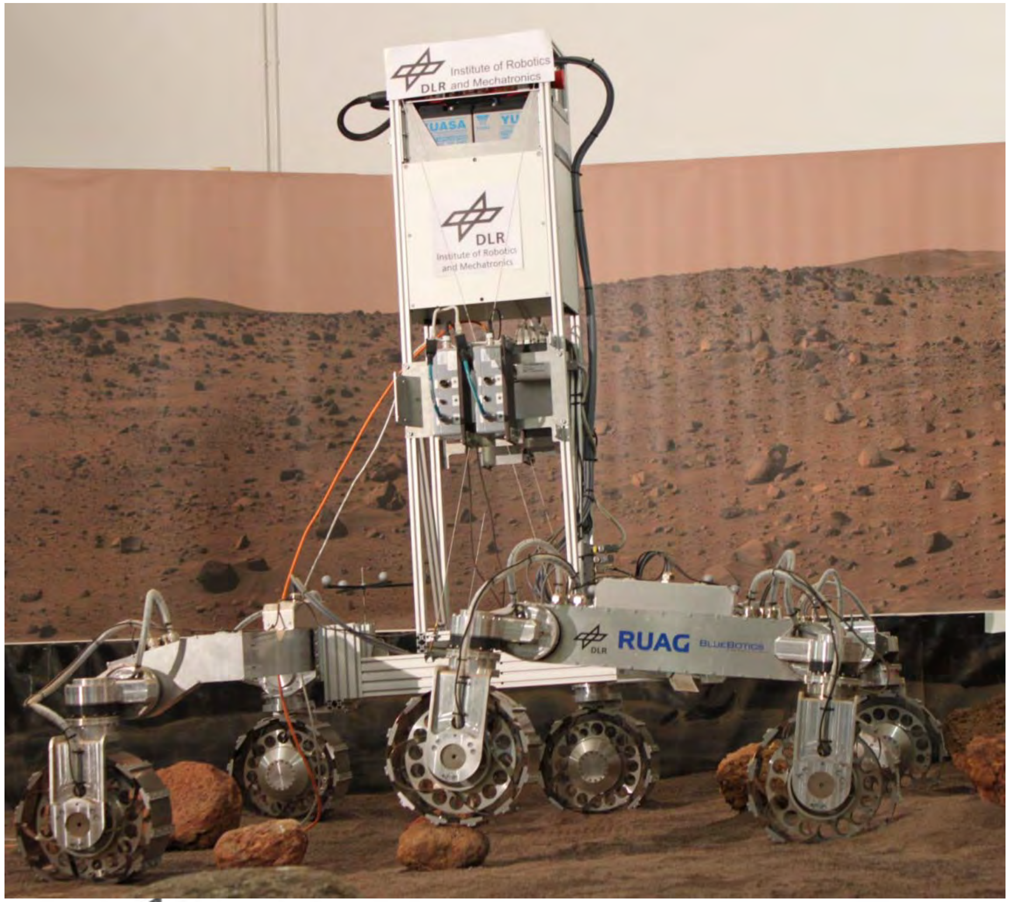
Movie:
Planetary
Exploration Lab -
Mars Rover Testbed

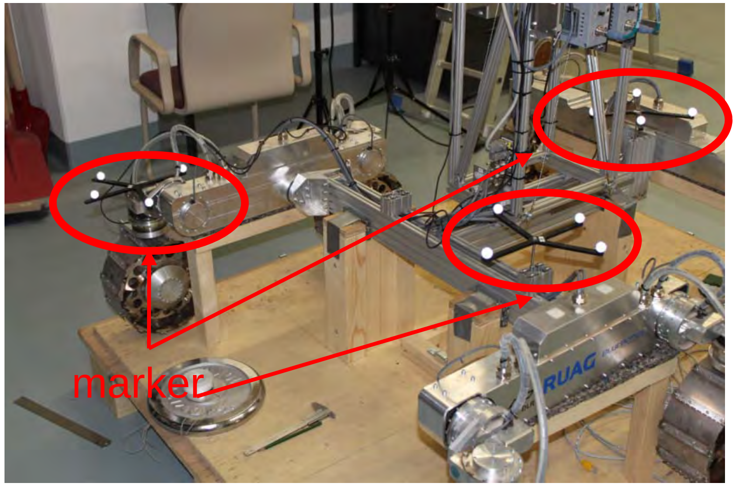


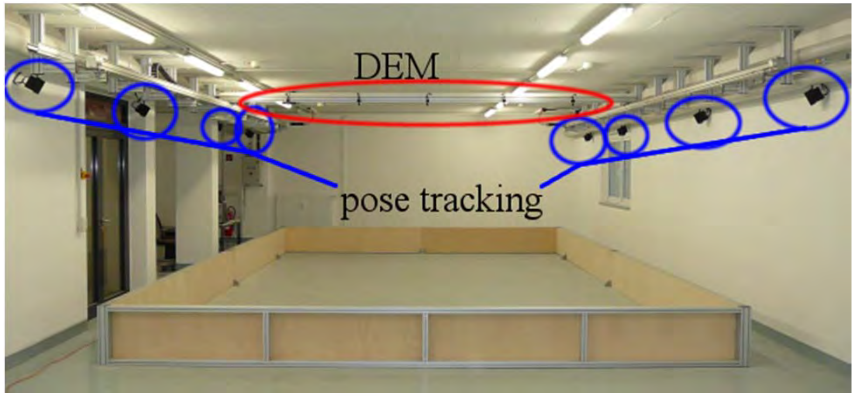


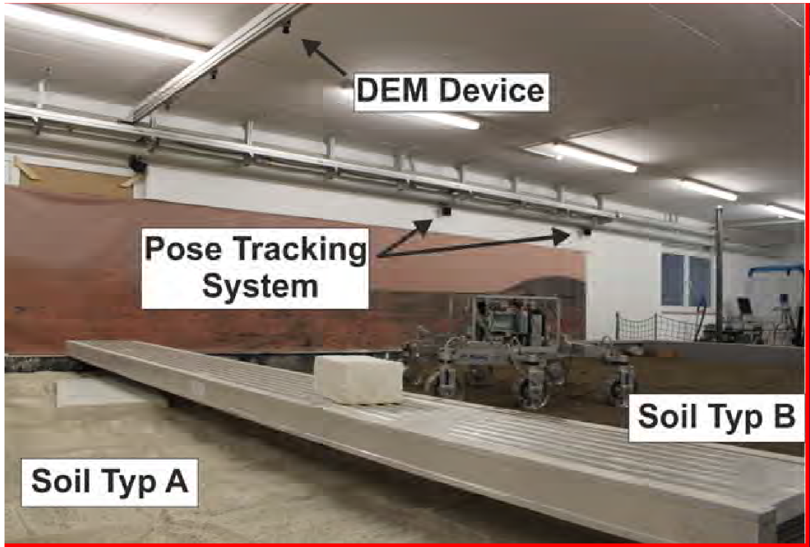
Planetary Exploration Lab PEL at DLR:

Verification of Simulations
for driveability dynamics etc. by testing in appropriate test facilities with almost realistic Moon and Mars soils, i.e. ‘soil simulants’

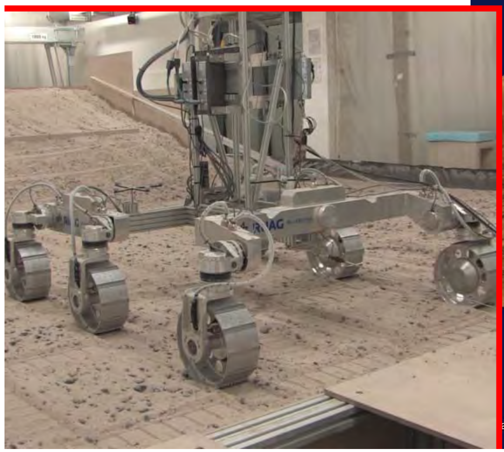

Institute of Robotics
DLR and Mechatronics
DLR
RUAG

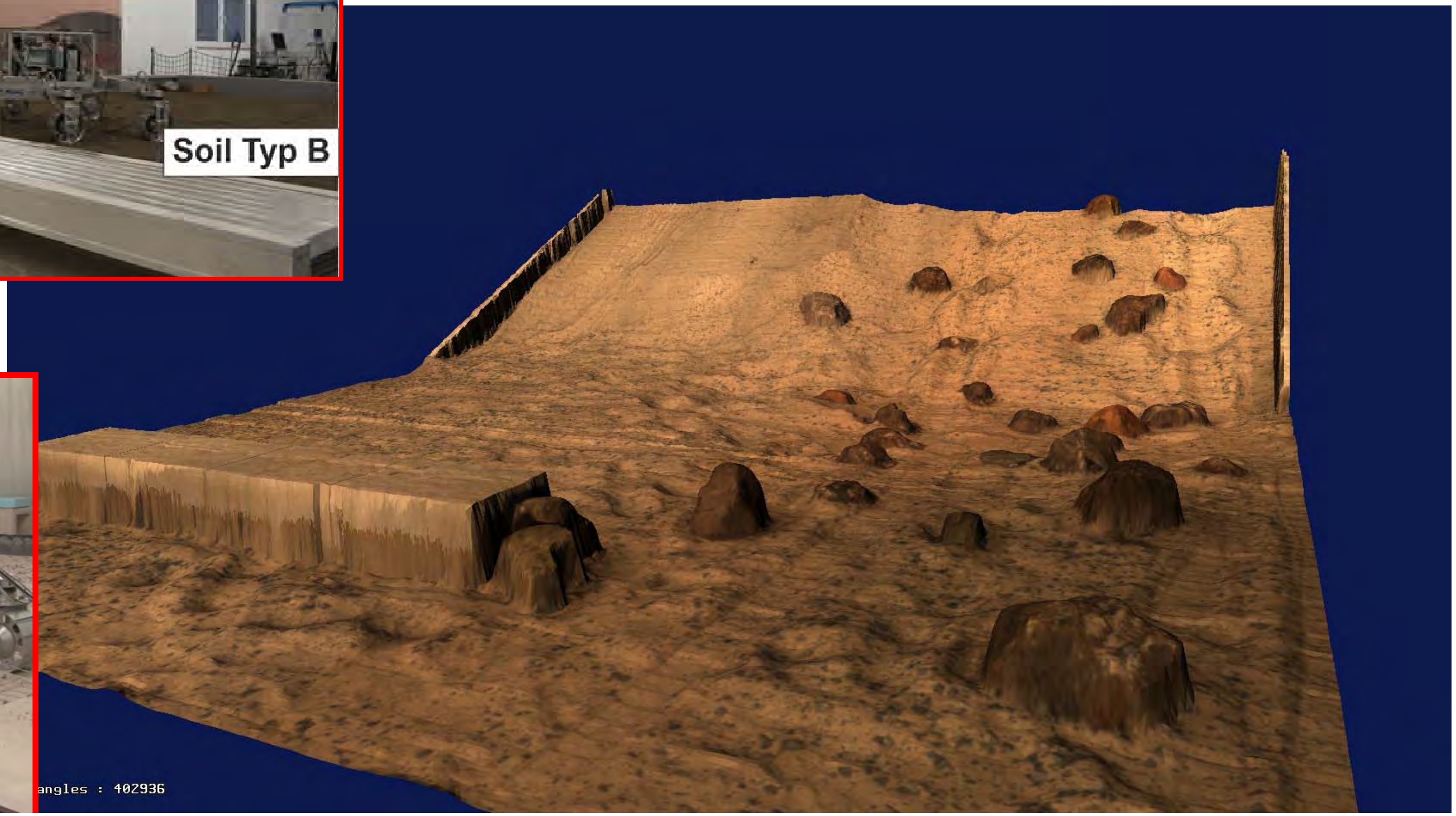

marker
RUAG


DEM
pose tracking



3D mapping (DEM) of testbed surface (SGM)
→ integration into software simulation



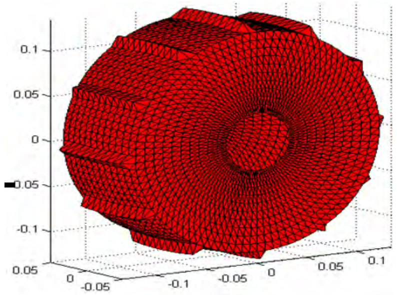


Multibody System and Contact Dynamics

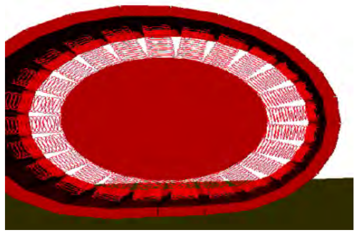
PCM based on Elastic Foundation Model

Multiple contacts

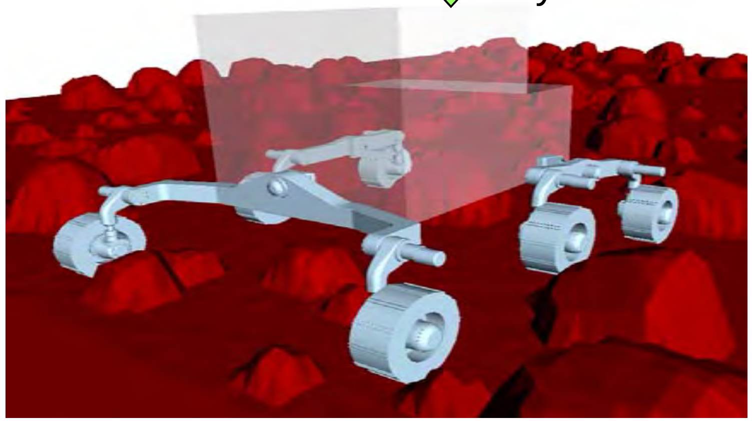
Wheel-soil slip

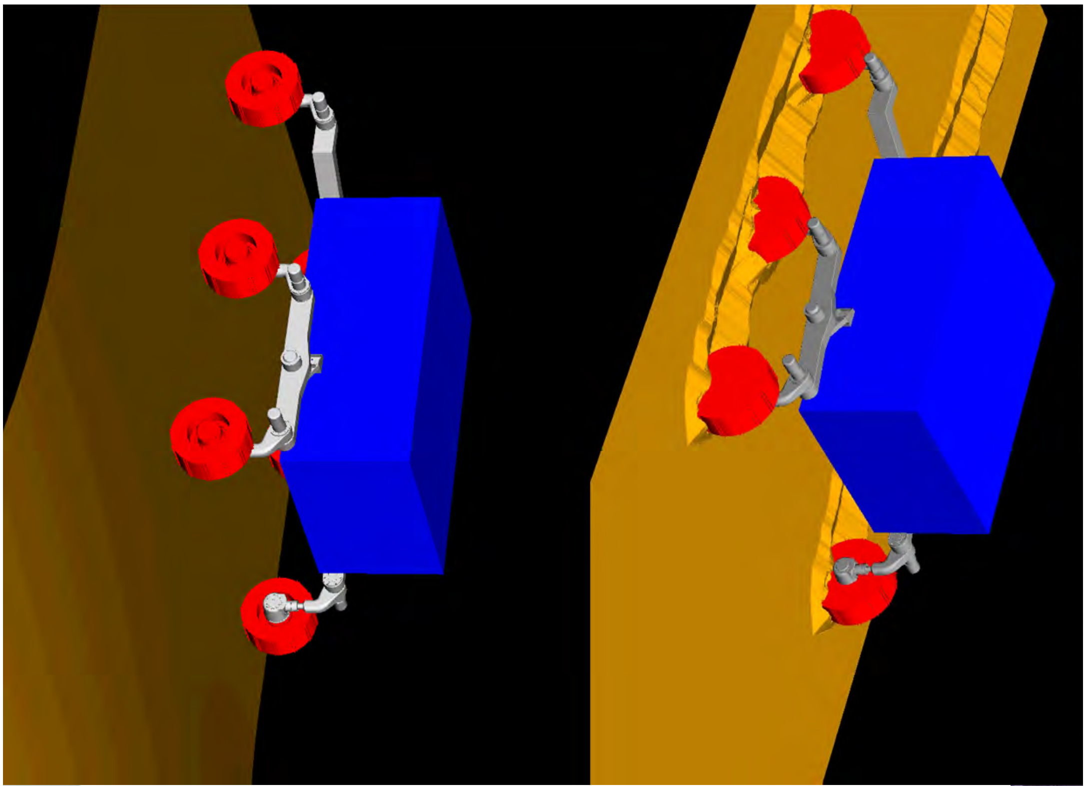


Defor-mable wheels

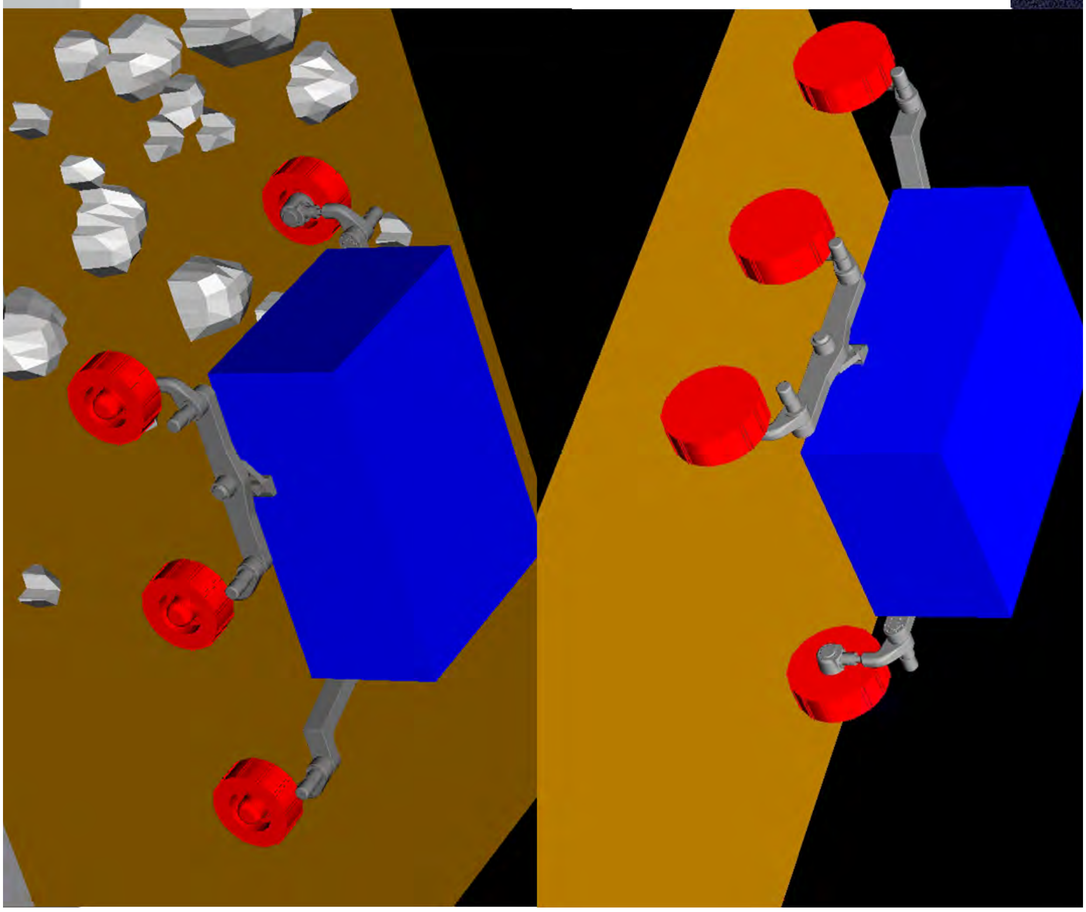


MBS
Multibody System

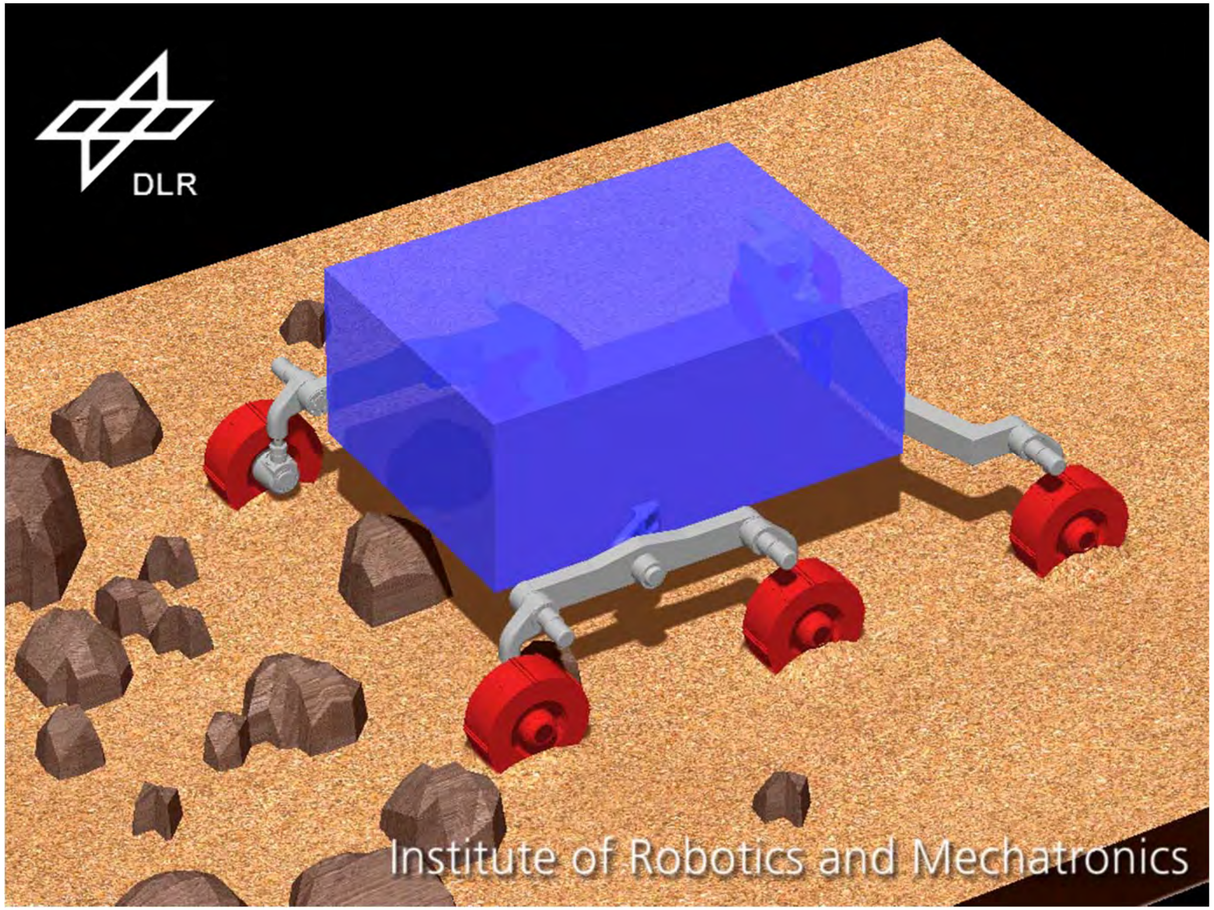




Simulation of important driveability effects on soft and rigd soils: ‘bulldozing + multipass’ + more generally compound terrains

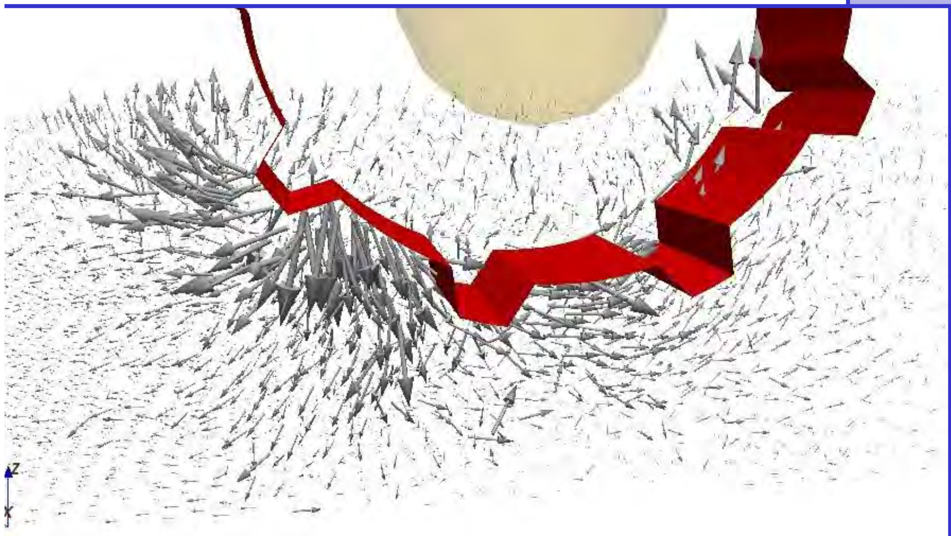


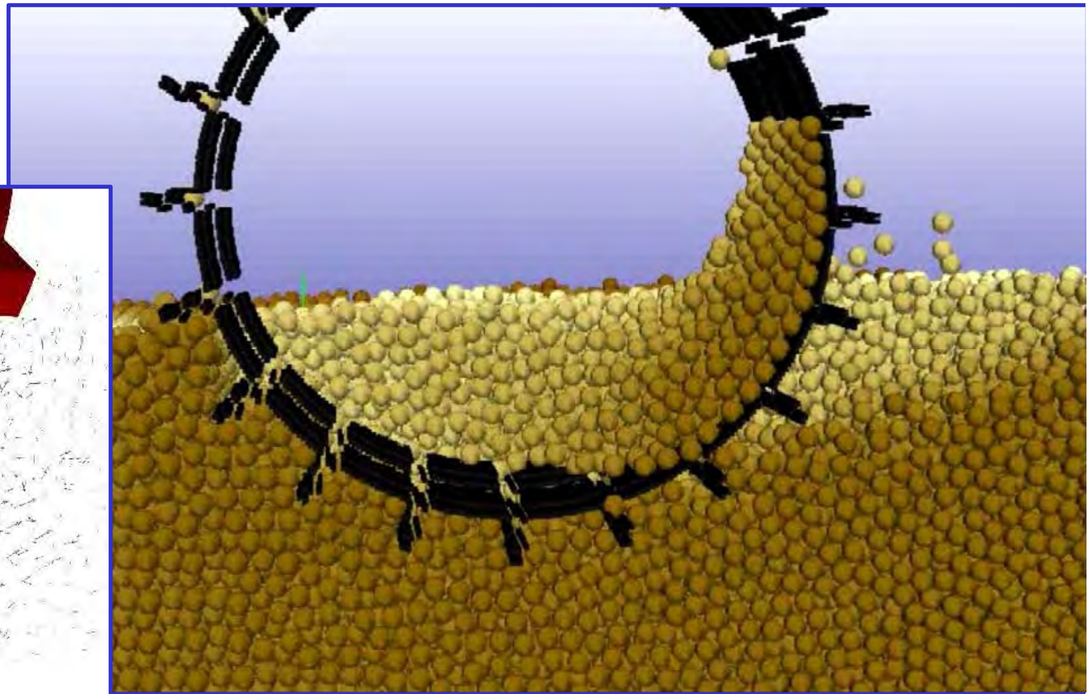
Rover driving over rigid and soft surfaces

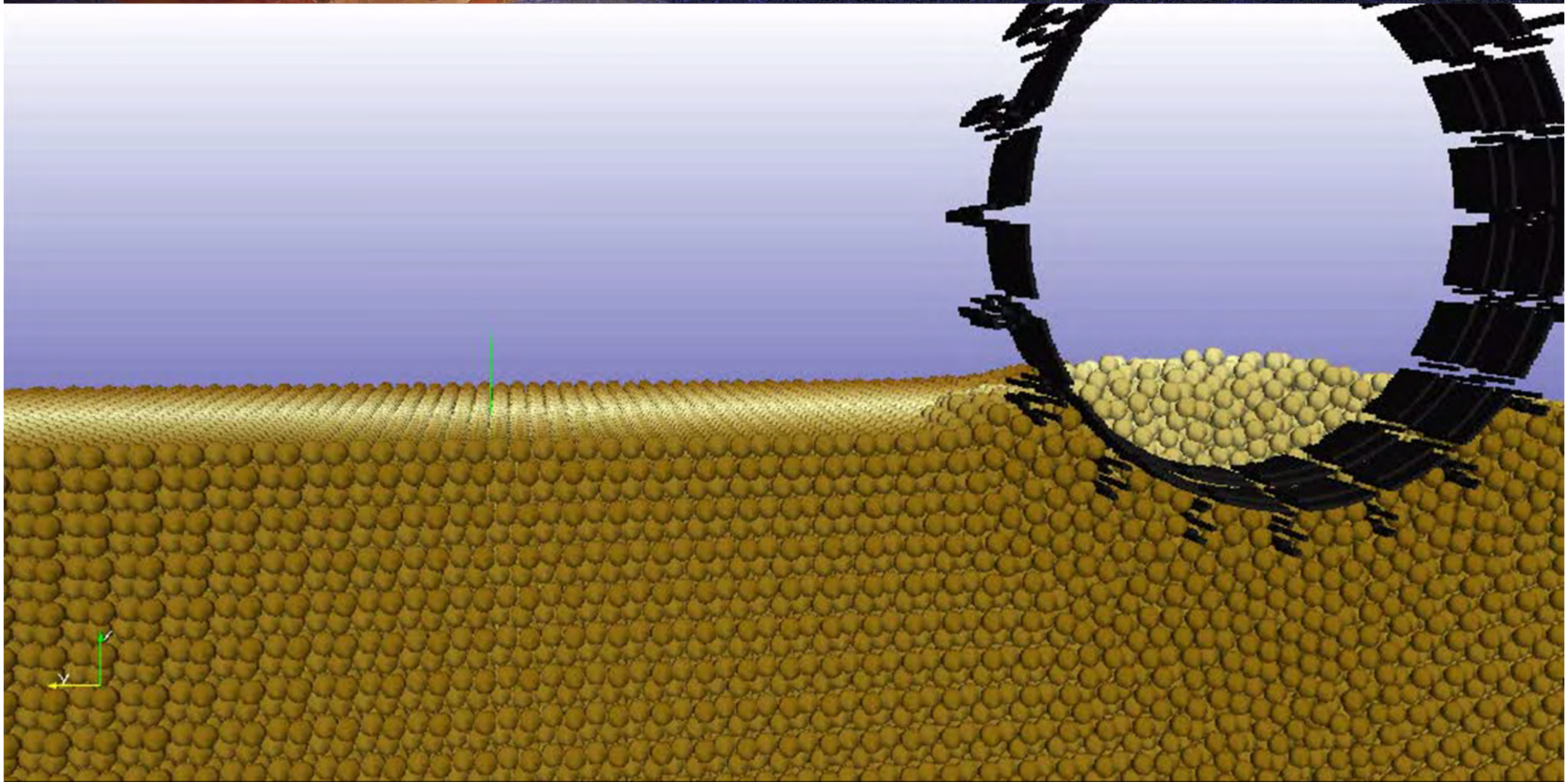


A different modeling approach: Particle based methods, mesh-free

DEM Discrete Element Modeling of soft soils interacting with rigid wheels



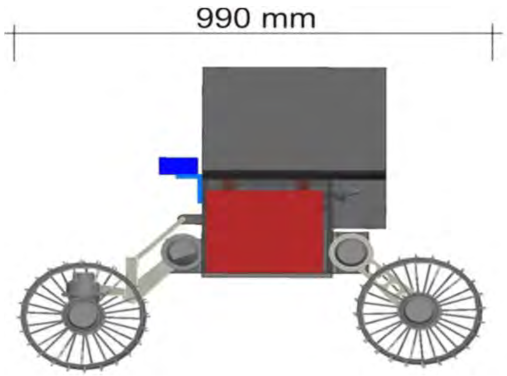


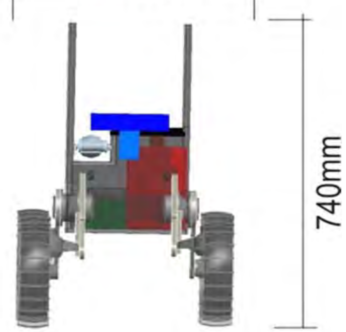


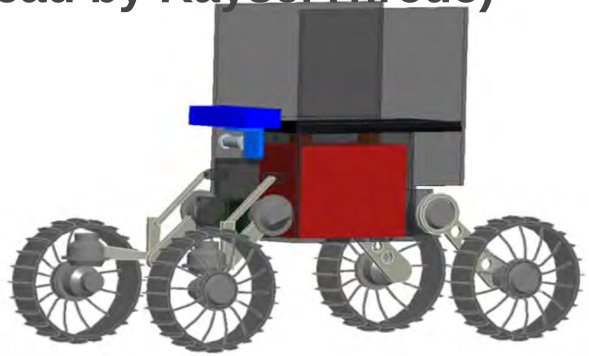
Basic Technologies
Developed at RMC

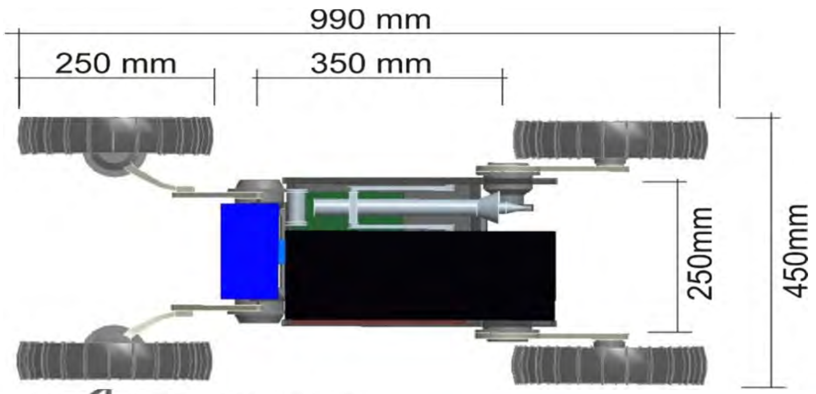
Participation in
Planetary Exploration Applications

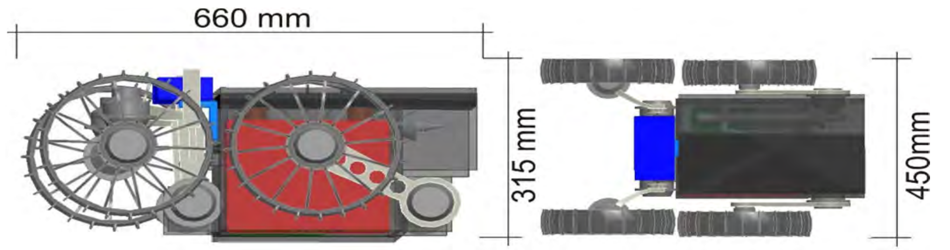
(1) Mobile Payload Element MPE – Moon Rover ~ 15 kg
(lead by KayserThrede)



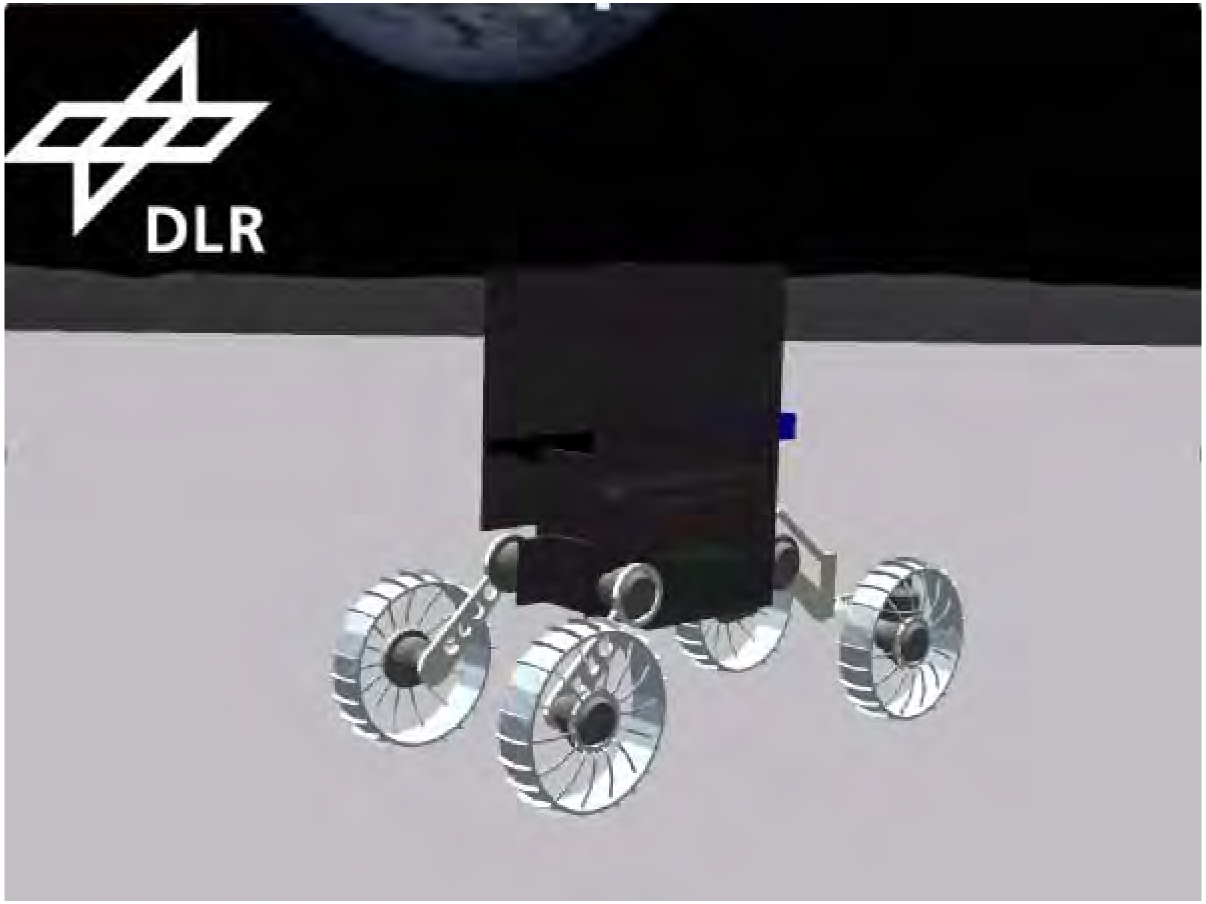








Stowed Configuration



Movie:
MPE – Mobile Payload Element for Next Lunar Lander Mission

June 29, 2011 | 2:35 pm

ROV-E Lightweight Technologies for Exploration Rovers

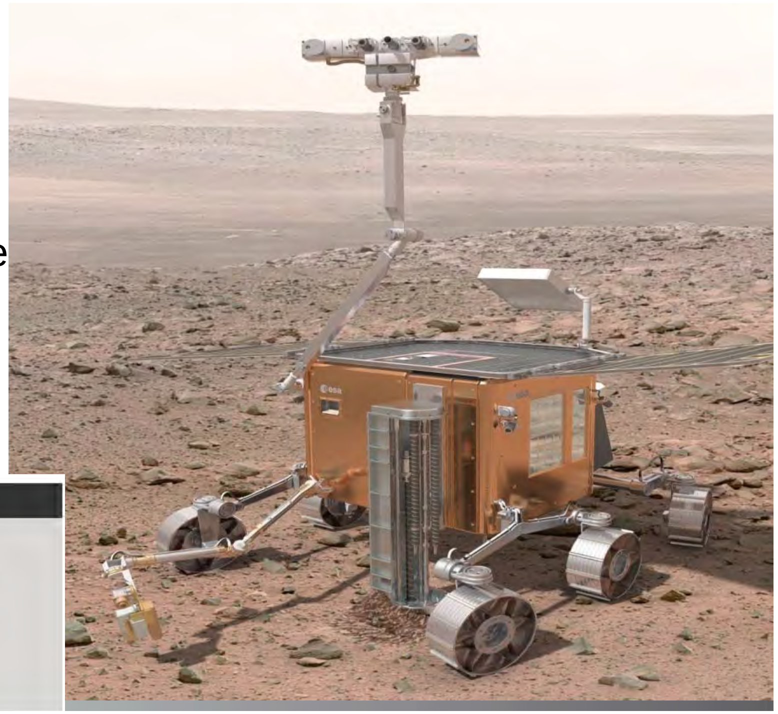
(2) Mars: ROV-E EU-Projekt (2011→ 3 years)

Challenge:

Reduce weight for all subsystems

DLR-RMC:

- responsible for innovative / optimized locomotion system
- modelling, simulation, optimization of driveability performance
- development & set-up of innovative actuator concept
  for wheel driving and steering;
- torque and slip control.
- breadboarding: single wheel or double wheel testing



PROJECT PARTNERS

tecnalia Inspiring Business

ThalesAlenia Space

DLR Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft

umeco composites

YUZHNOYE design office

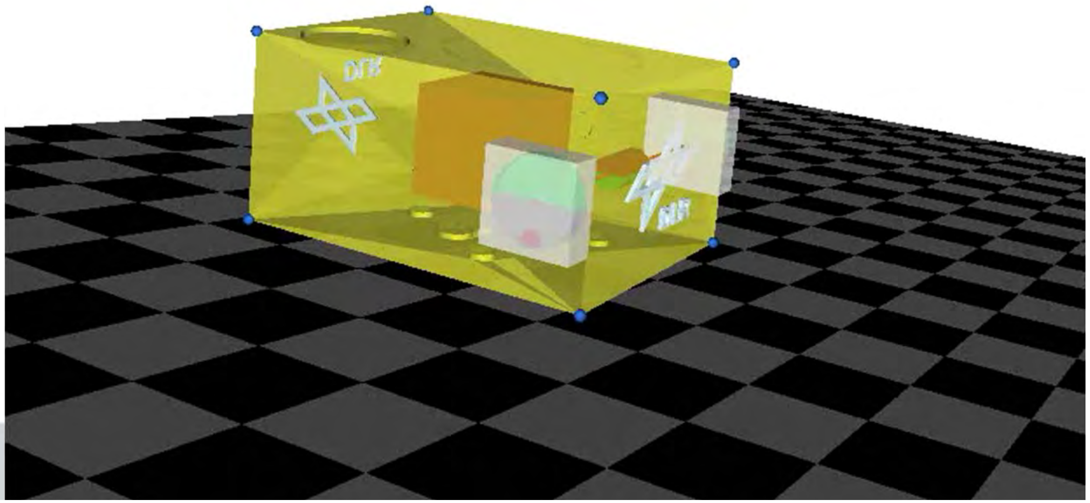
University of Southampton

(3) MASCOT - Mobile Asteroid Surface Scout Mission
(German payload on 2014/15 Hayabusa-2 Japanese mission)

Very low gravity: 10^{-5} g

Provide mobility by
1. self-uprighting &
2. hopping over planetary surface

Zero-g flight testing in Feb 2012:
Parabola flights by NoveSpace Bordeaux



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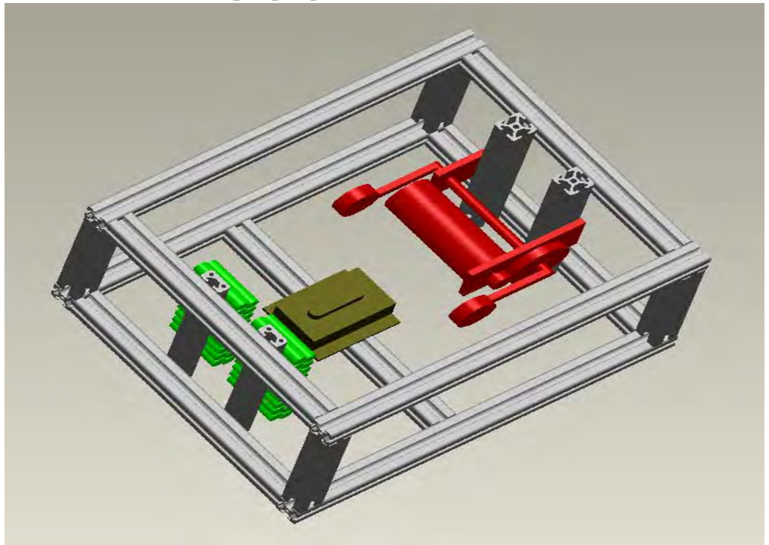
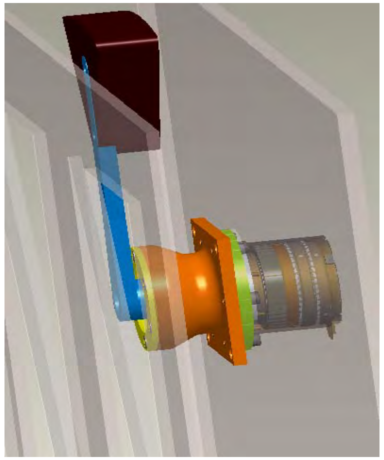
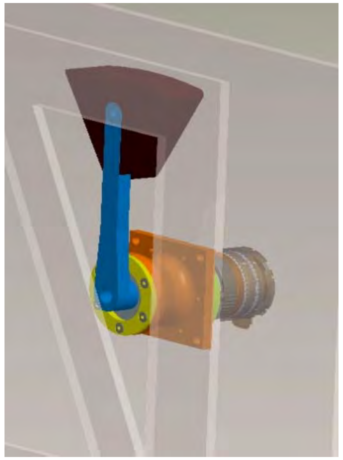
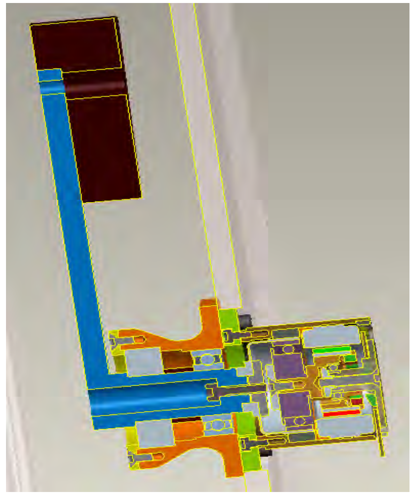
MASCOT



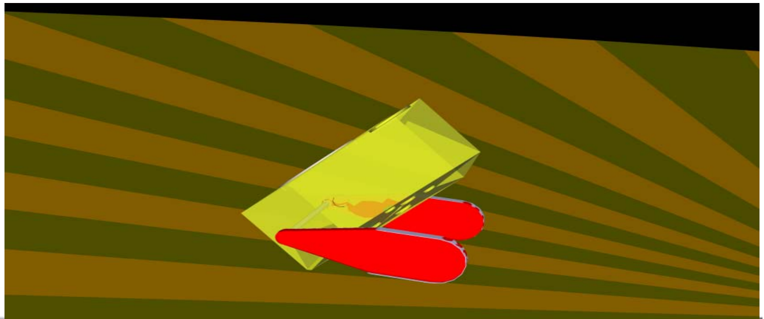






New design: only 1 excentric mass + motor, contr.

First design approach: 2 excentric massesExzenter
+ 1 motor, controlled

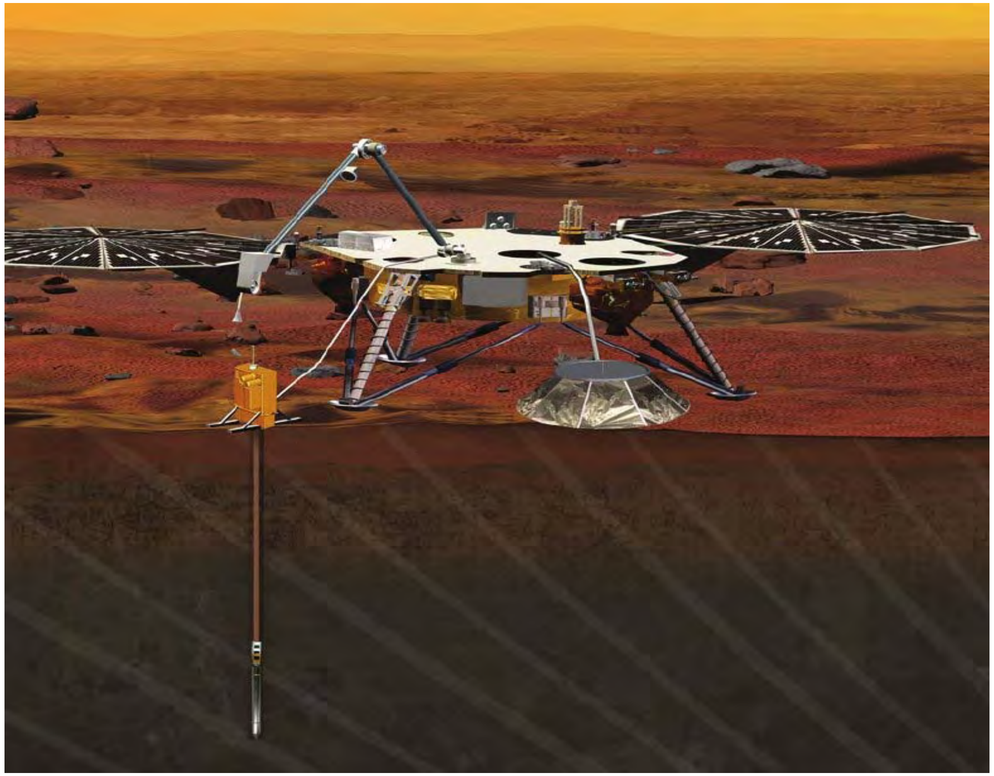


Conventional concept:
two arms (2 paddles) controlled

(4) InSight = (Mars) Interior Exploration using Seismic Investigations, Geodesy and Heat Transport

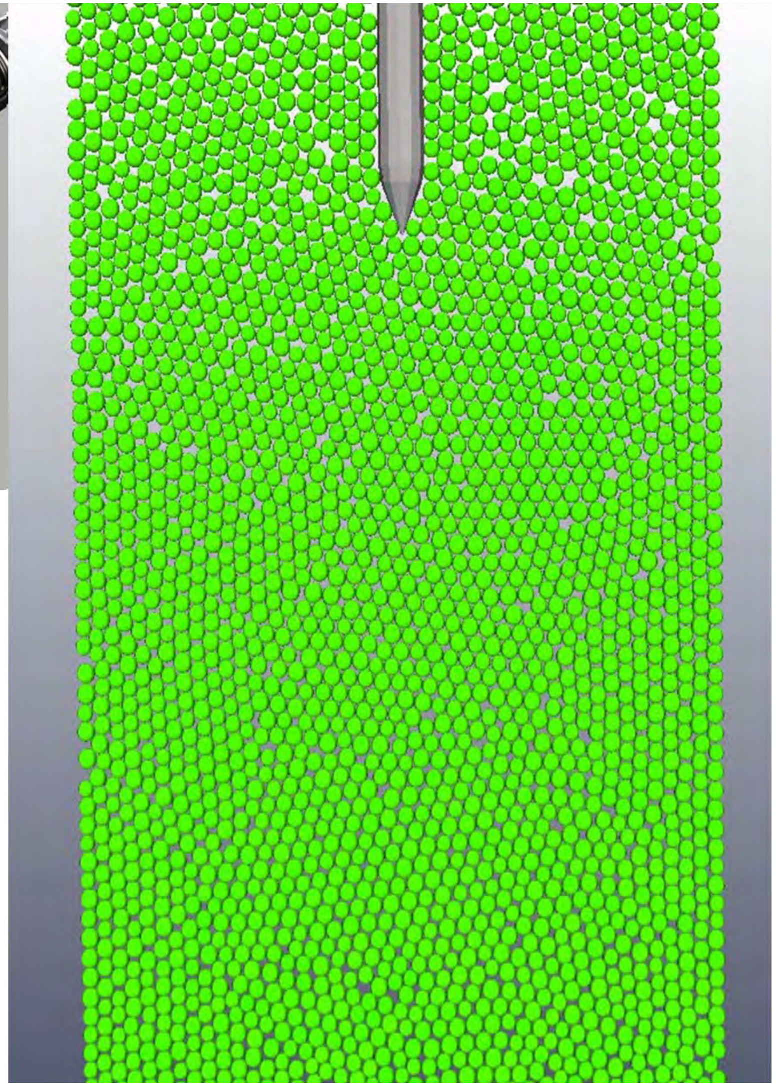
- Phoenix mission lander
- Launch: March 8 - March 27, 2016
- Landing: September 20, 2016
- Surface operations: 720 days
- End of Mission: September 18, 2018

Goal: understanding the processes that shaped the rocky planets of the inner solar system



DLR payload contribution
(lead by DLR Inst. PF, Berlin):

HP³ Mole - Heat Flow and Physical
Properties Package



(5) ROBEX - visionary long-term cooperative (national) endeavour

HELMHOLTZ
GEMEINSCHAFT

5 years: Oct 2012 – Sep 2017

http://www.robex-allianz.de/

Space and Deep Sea come together

ROBEX

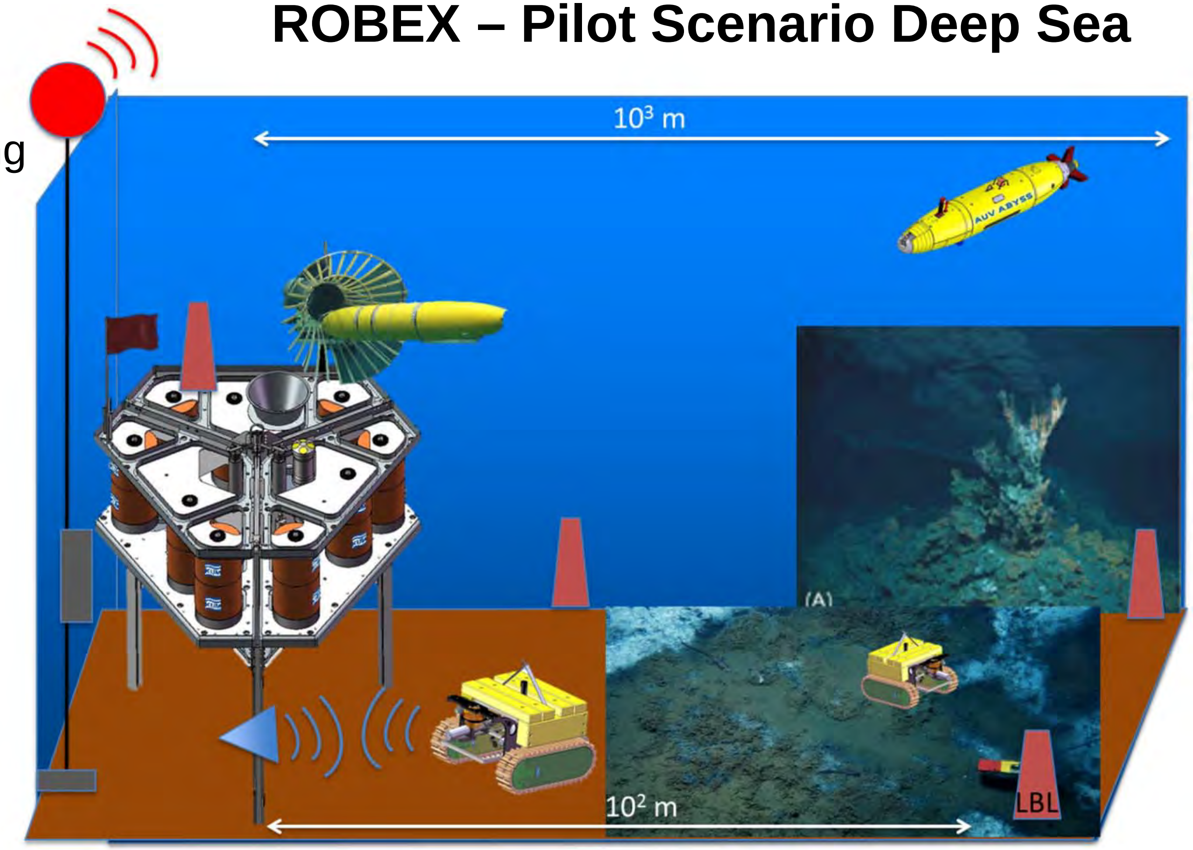
Benefit from each other:

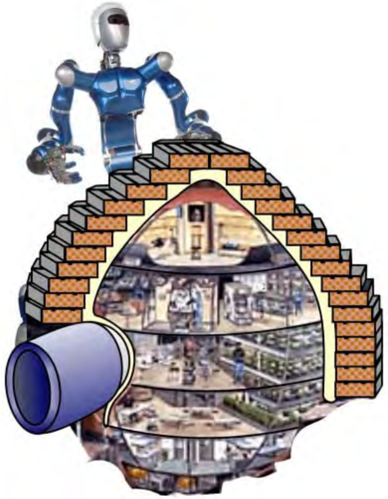
- Autonomy
- Autonomous localization, mapping & navigation
- Autonomous vehicles
- Autonomous manipulation
- Docking / interfaces
- Energy supply
- Communications
- and more

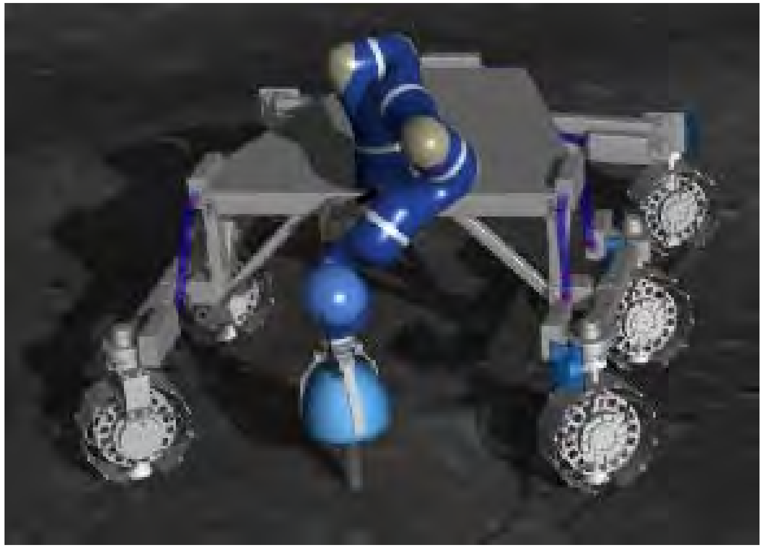
Partners:

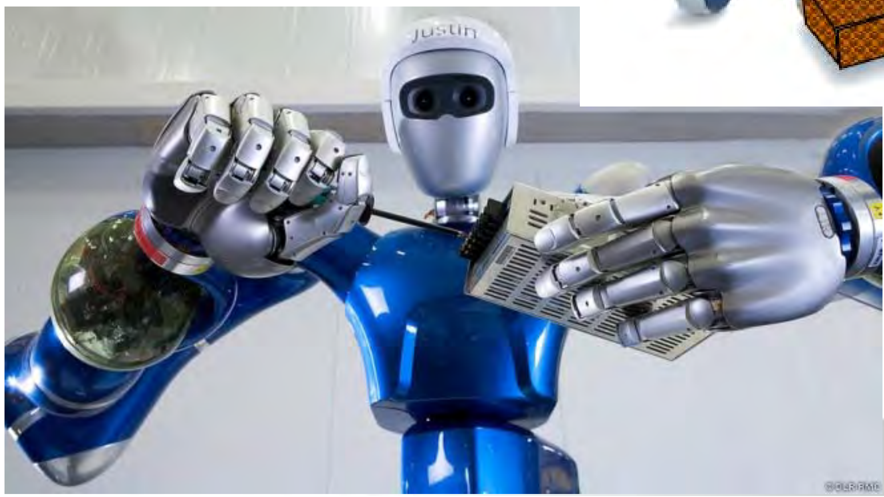
- HG centers: DLR, AWI, Geomar
- Universities: TUKL, TUD, TUB, TUM, JUB, Marum
- DFKI

ROBEX – Pilot Scenario Deep Sea





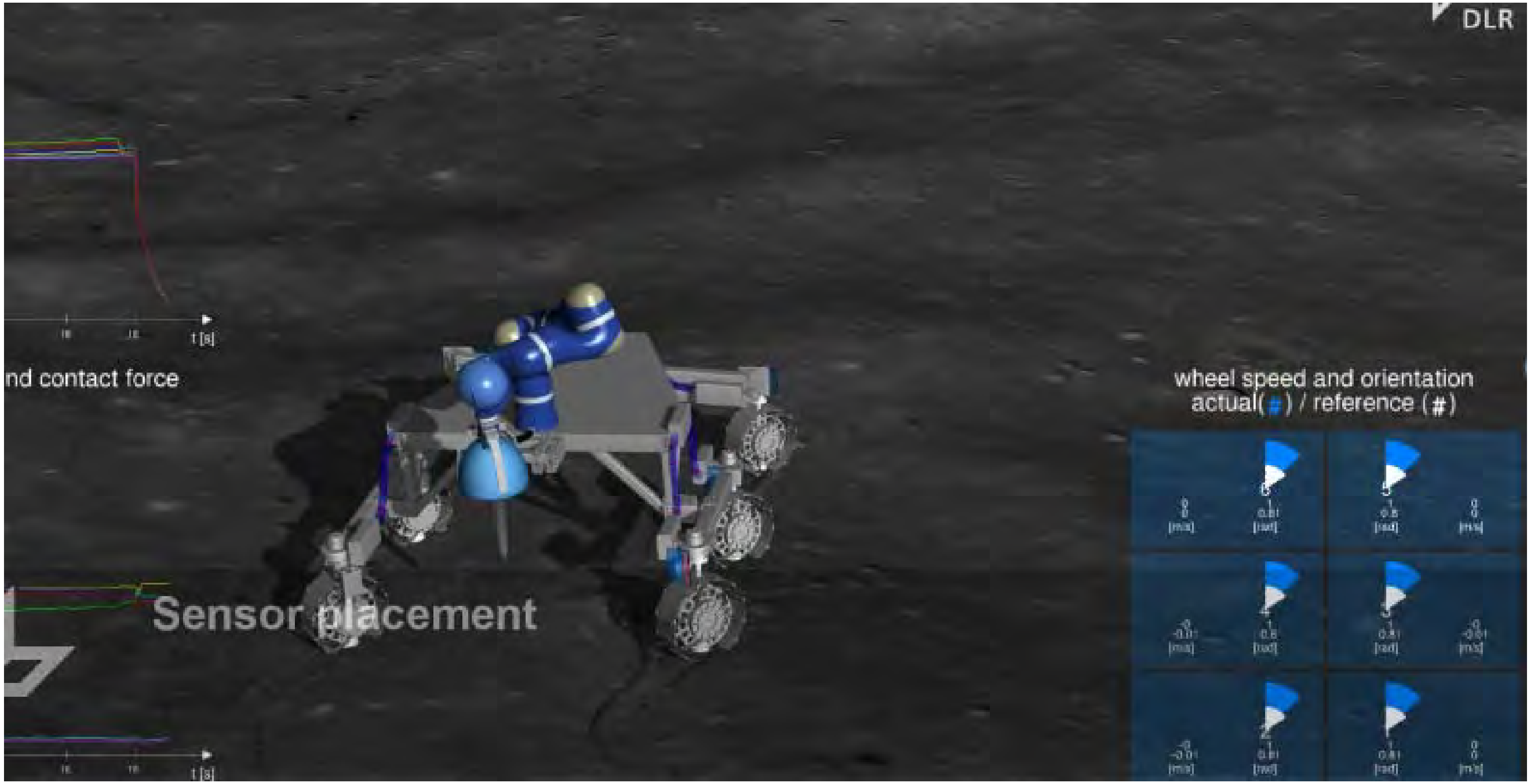




ROBEX –

Making use of capabilities for mobility and manipulability on Moon‘s surface

Pilot scenario Moon: ASN Active Seismic Network Deployment

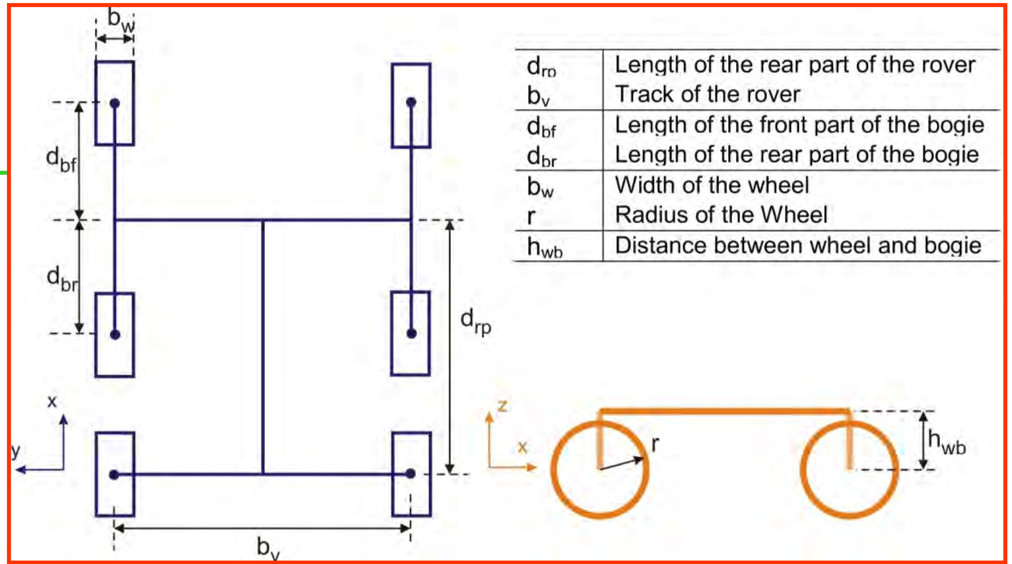


Movie:
ROBEX - ASN Visuali-zation

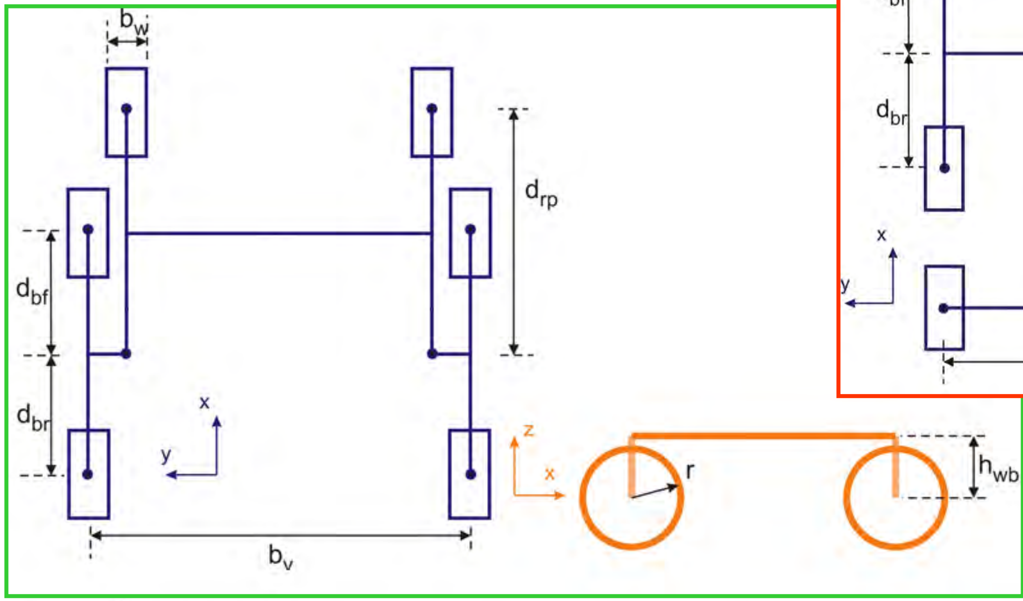
(6) Optimization - 2 well-known examples:

ExoMars Rover (ESA)

Rocker-Bogie Rover (NASA)



d_{rp}	Length of the rear part of the rover
b_v	Track of the rover
d_{bf}	Length of the front part of the bogie
d_{br}	Length of the rear part of the bogie
b_w	Width of the wheel
r	Radius of the Wheel
h_{wb}	Distance between wheel and bogie



ExoMars Rover

Rocker-Bogie Rover

Example of optimization process for rover geometric parameters

Terrain scenario: first driving on soft soil and over a rock, then driving on hard soil a step downwards including a rock as obstacle

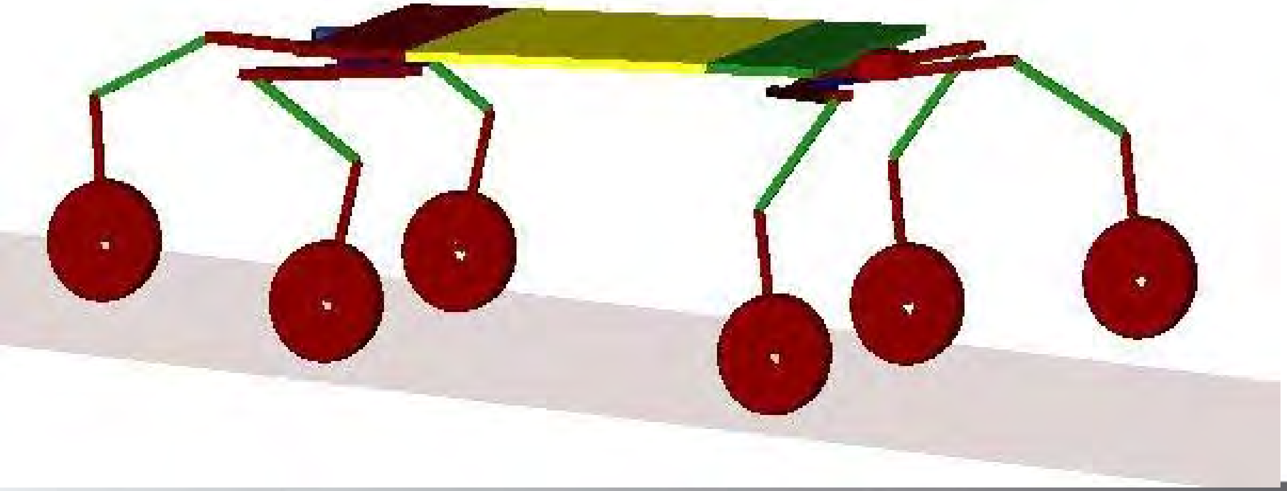
Movie:
Optimization of ExoMars rover locomotion subsystem -
geometric and kinematic properties using genetic algorithms

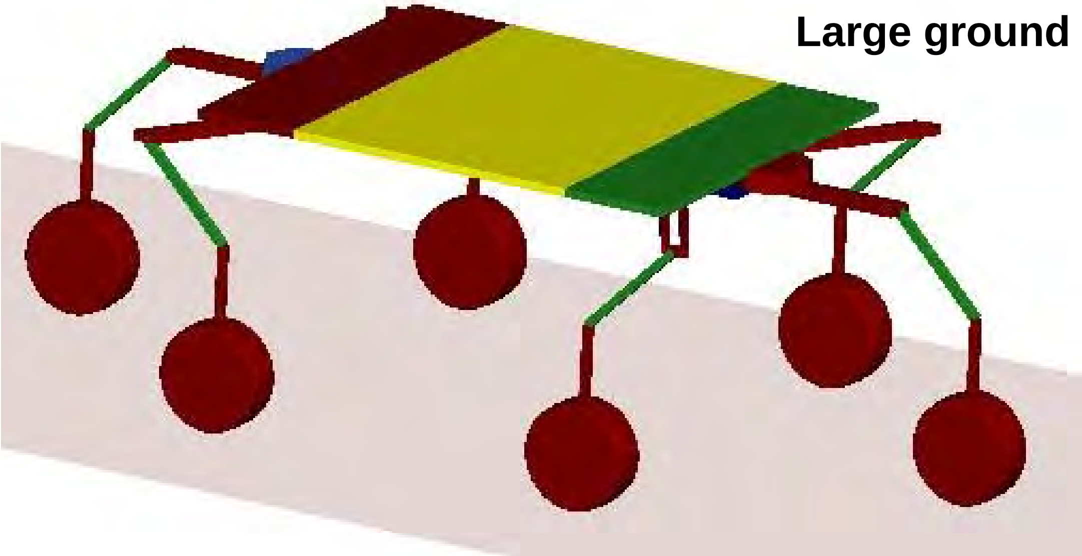
(7) Advanced Kinematics Concepts

Legs and Wheels combined – a first approach

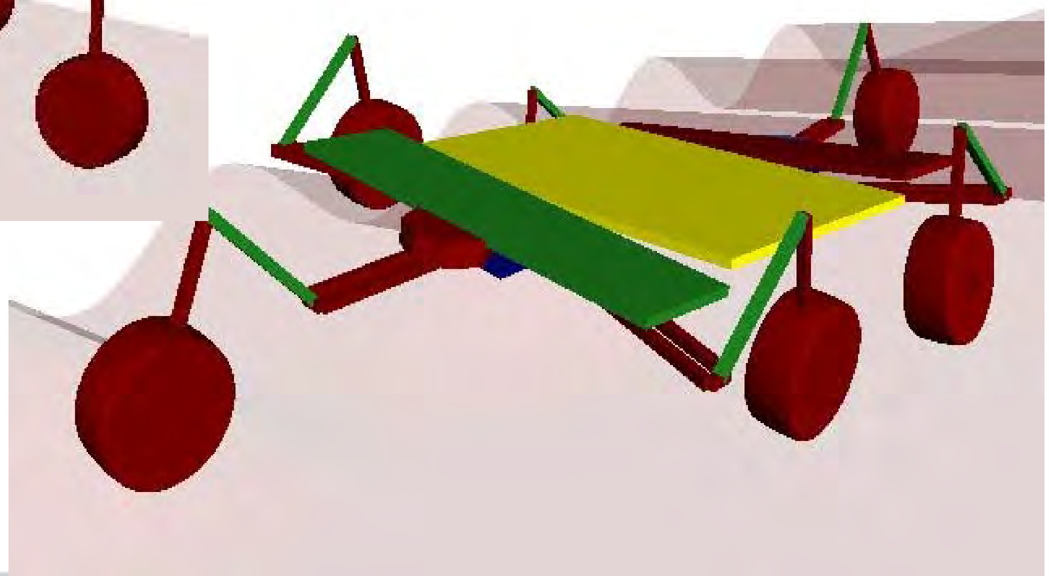
Design features:

- 6 articulated legs + 6 wheels
- 3 legs suspended in front and 3 legs in rear, passively
- central body coupled by differential gear
- each leg has 3 dof
- connecting plate for 3 legs
  attached to central body
  replaces bogie suspension
  in ExoMars type rovers





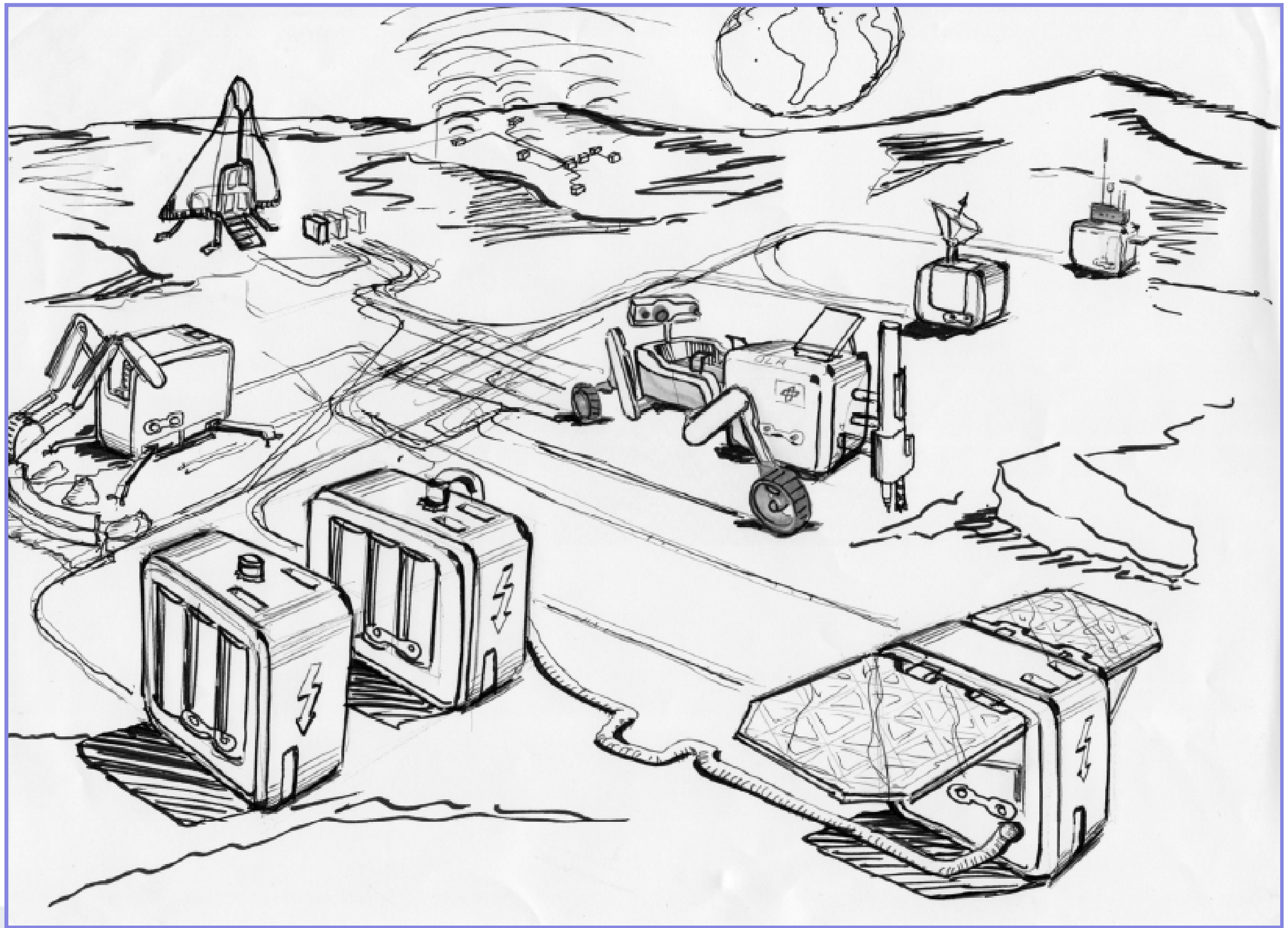
Large ground clearance and high CoM (Center of Mass)



Passive suspension on rough terrain with low CoM

(8) Potential Exploration Scenarios on Moon:

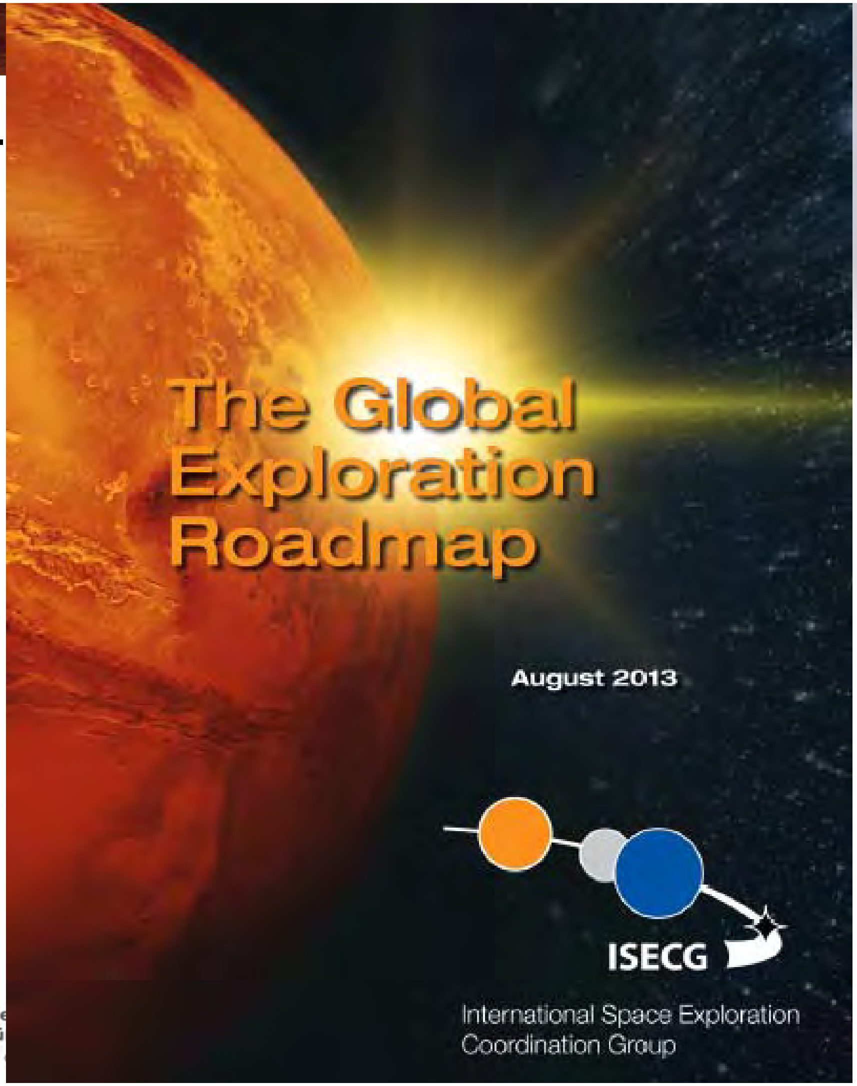
- working vehicles
- manipulation skills
- energy and comms. stations
- docking and interface elements
- almost fully autonomous ops.



ISECG –

Internat. Space Explo- ration Coordi- nation Group

DLR is partner in ISECG



What is New in the Global Exploration Roadmap?

The initial release of the Global Exploration Roadmap in September 2011 provided an opportunity for stakeholders across the globe to engage in national and international dialogue about space exploration to destinations where humans may someday live and work. Ideas and feedback generated through this dialogue have strengthened agency planning efforts and led to some of the changes included in this version.

The initial roadmap identified two potential pathways toward the driving goal of human exploration of Mars: "Asteroid Next" and "Moon Next." Each pathway was expanded through conceptual mission scenarios, which served as references to inform preparatory activities. Building on this work, the 2013 roadmap includes a single reference mission scenario that reflects the importance of a stepwise evolution of critical capabilities which are necessary for executing increasingly complex missions to multiple destinations, leading to human exploration of Mars. The roadmap demonstrates how initial capabilities can enable a variety of missions in the lunar vicinity, responding to individual and common goals and objectives, while contributing to building the partnerships required for sustainable human space exploration.

Participating space agencies continue to prepare for human exploration beyond low-Earth orbit. The expanded chapter on preparatory activities reflects accomplishments in the five original areas: ISS utilization, robotic missions, advanced technologies, next generation capabilities, and analogues. A sixth section has been added, focusing on human health and performance risk mitigation.